Fourth Annual Conference on Carbon Capture & Sequestration

Developing Potential Paths Forward Based on the Knowledge, Science and Experience to Date

IEA GHG Weyburn CO_2 Monitoring and Storage Project: An International Collaborative Research Program Led by the PTRC Based in Regina, Saskatchewan, Canada

Weyburn Project Research Activities

A MECHANICAL EARTH MODEL FOR THE WEYBURN CO_2 MONITORING AND STORAGE PROJECT

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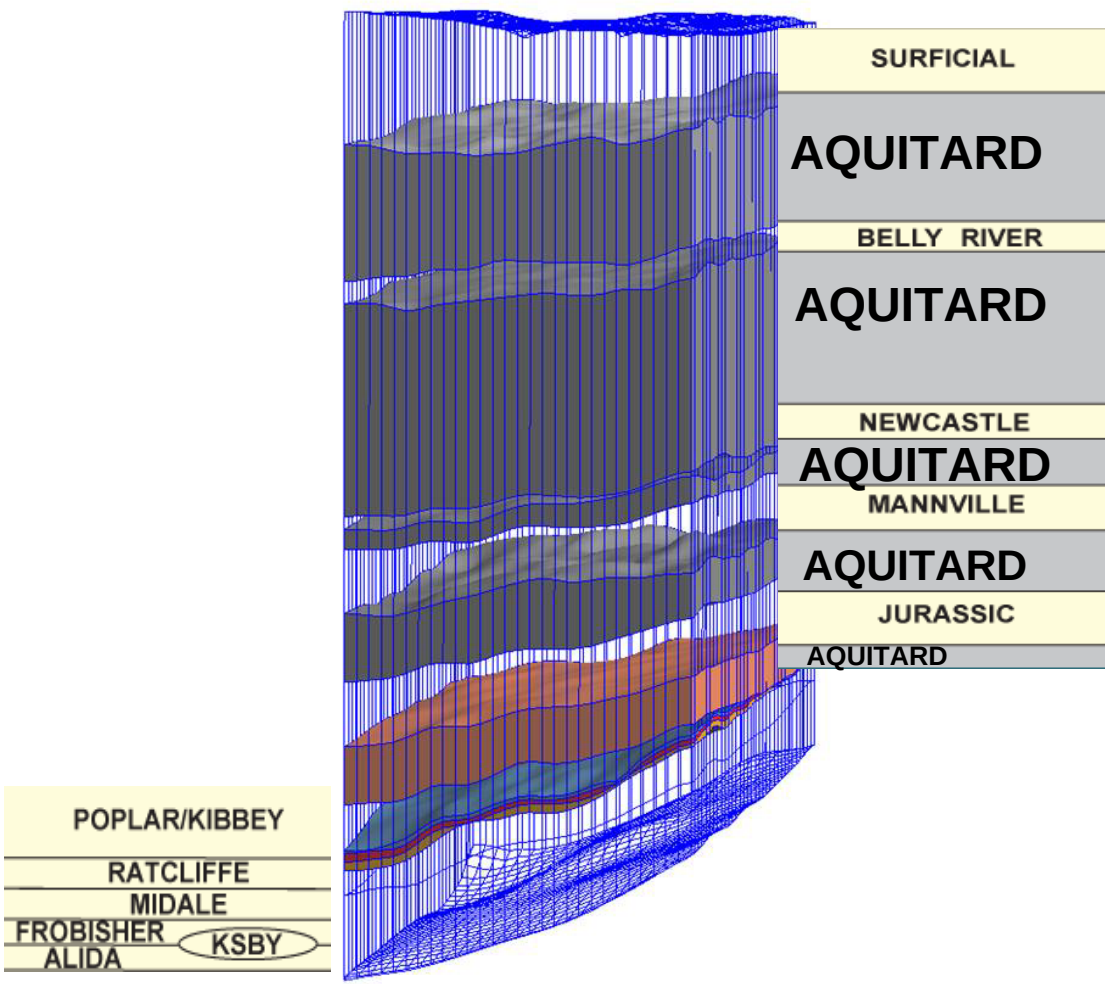
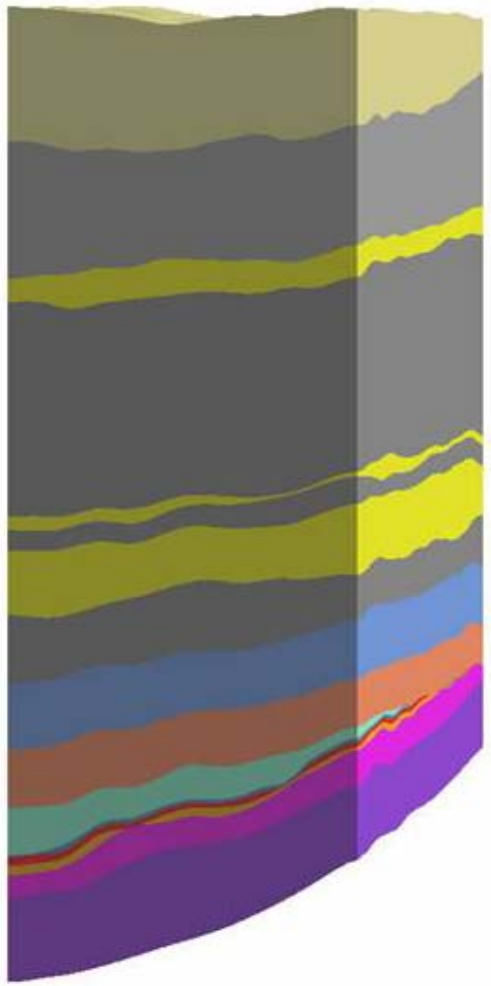
What is a Mechanical Earth Model?

- A logical compilation of relevant information about earth stresses and rock mechanical properties based on geomechanical studies and geological, geophysical and reservoir engineering models.
- Forms part of a performance assessment to determine the integrity of the reservoir and its bounding seals.
- Elastic properties from the Cretaceous Mannville Group down to the Mississippian Frobisher Beds were computed.
- The Mannville Group was chosen as an upper limit because of its large flow velocity, as any CO_2 potentially leaking upwards would likely be carried away laterally by this aquifer.

Weyburn CO_2 Storage System





Mechanical Properties of Formations

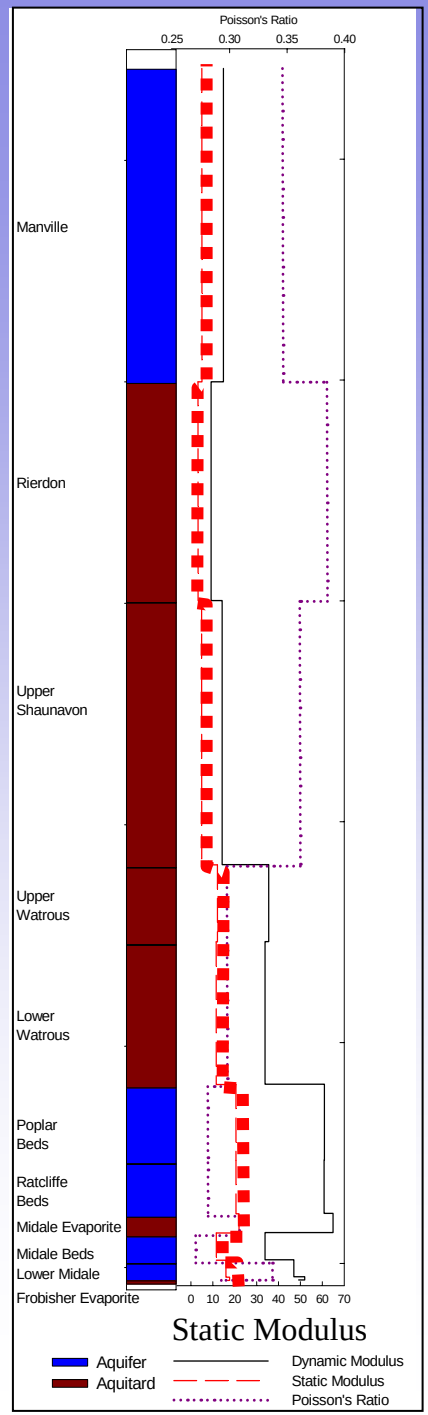
Property / *Formation*	Fracture Density (1/m)	Dynamic Properties		Static (Model) Properties		k (m^2)
		K (GPa)	G (GPa)	K (GPa)	G (GPa)	
Watrous	N.A.*	13.0[b]	9.0[b]	4.5[b]	3.0[b]	N.A.*
Midale Evaporite	0[a]	46.0[c]	24.0[c]	16.0[c]	9.0[c]	10^{-19} 10^{-21}
Marly Dolomite	0.4-0.7[b]	26.0[c]	13.0[c]	8.0[c]	4.0[c]	9.9^{-15}
Intershoal Limestone	3.0-4.0[b]	47.0[c]	21.0[c]	16.0[c]	7.0[c]	2.9^{-15}
Shoal Limestone	0.7-0.9[b]	37.0[c]	19.0[c]	12.0[c]	6.0[c]	4.9^{-14}
Frobisher Evaporite	N.A.*	41.0[c]	20.0[c]	14.0[c]	6.0[c]	10^{-19} 10^{-21}

*. Not available

[a]. Through an extensive review of all the evidence available and geomechanical modeling we have concluded that conductive fractures are not present in the Midale Evaporite.

[b]. Literature review

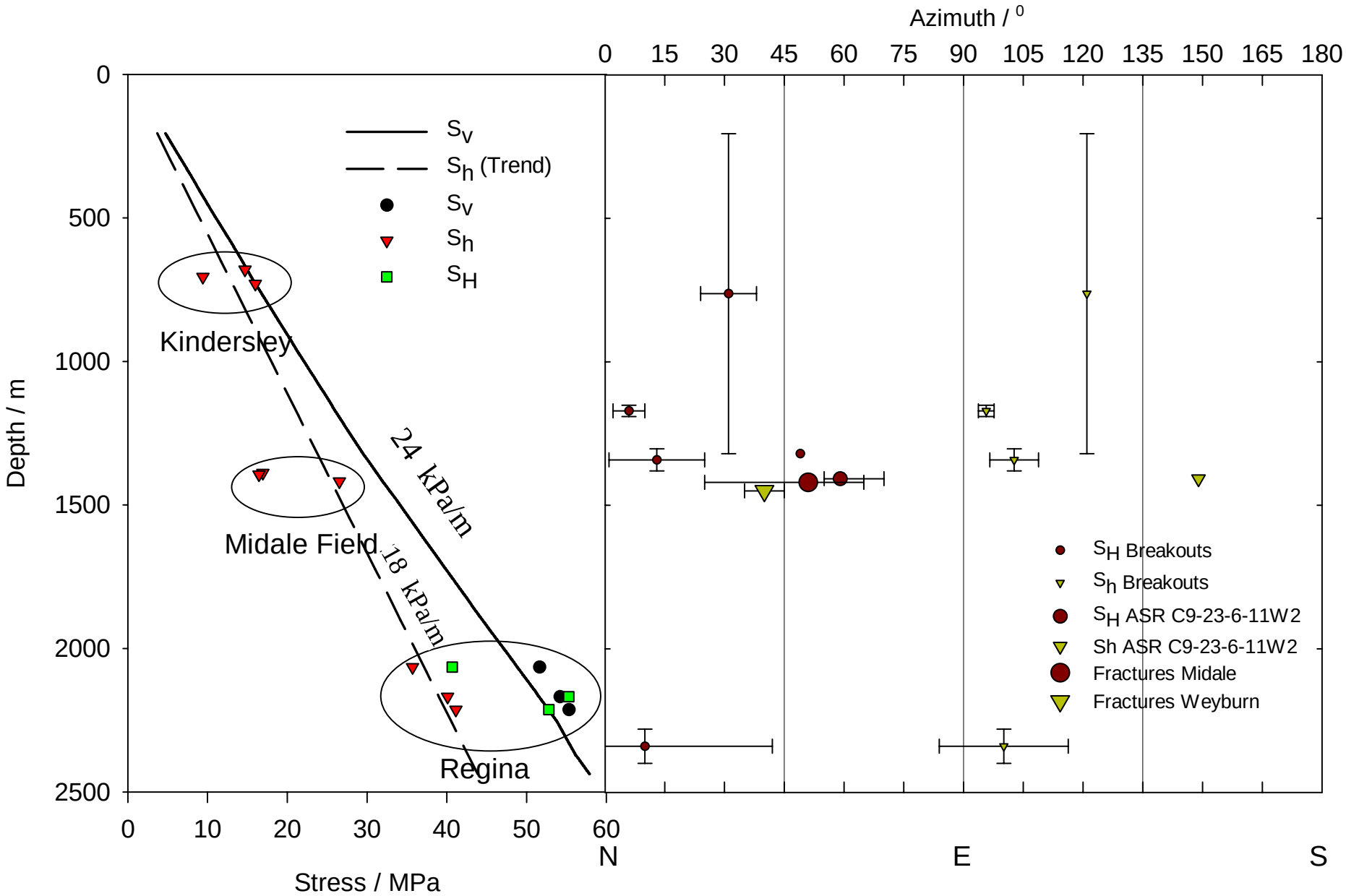
[c]. Laboratory testing – Dipole sonic logs - Literature review



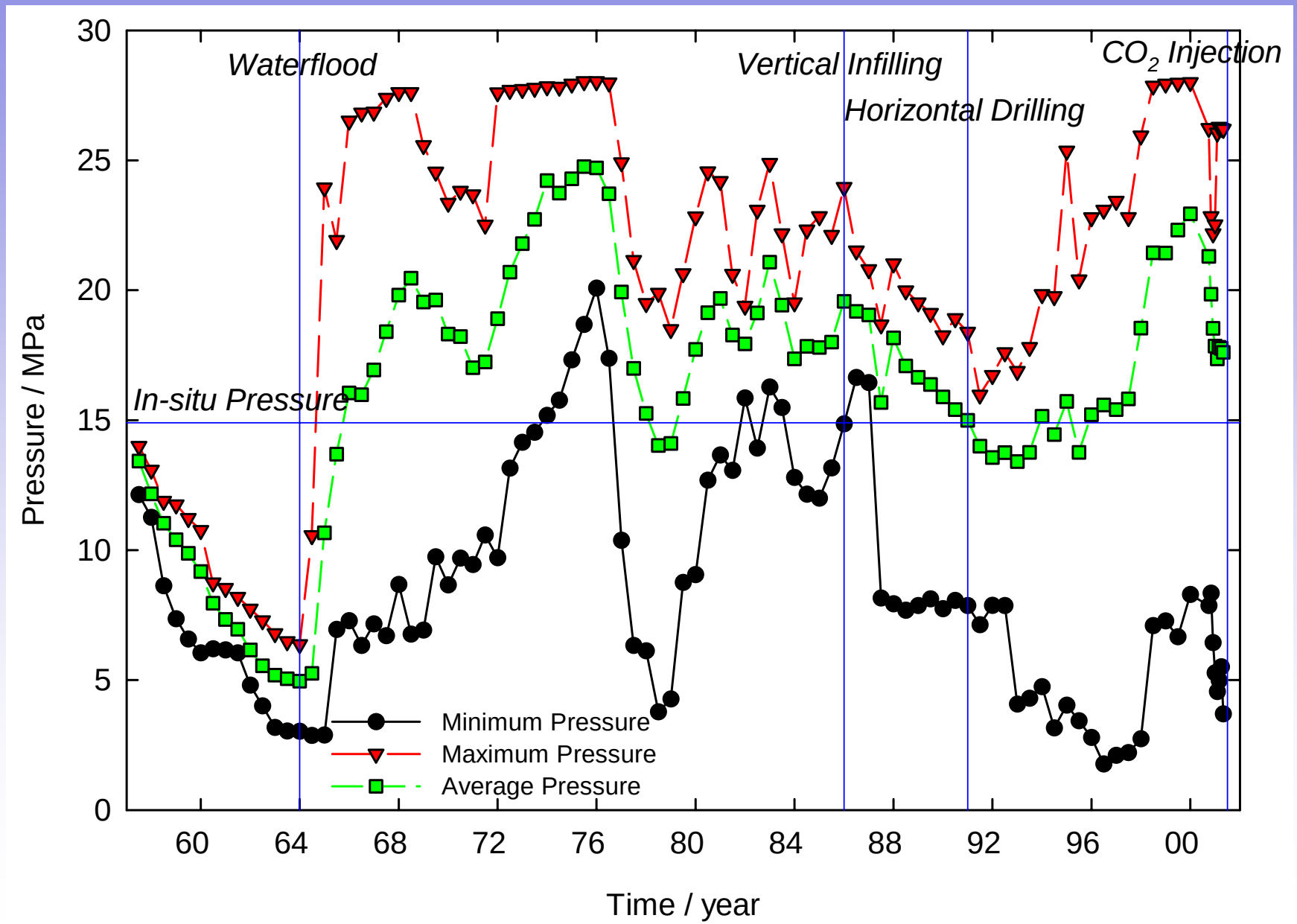
Fractures and In Situ Stresses

- **NE-SW trending set** of fractures in reservoir controls the flow, but there is also a secondary set in the NW-SE direction.
- **Fractures believed to have a tectonic origin.** Compressive stresses lead to tensional failure, accompanied by rotation and dragging of pre-existing structures.
- Azimuth of σ_H' is ~ 40-50°, whereas σ_h' is ~ 130-140°.
- The vertical *in-situ* stress was obtained from density logs, with an average unit weight of 24 kPa/m. Minimum in-situ stress measurements made in southeastern Saskatchewan (near Regina and within the Midale Field) seem to indicate a minimum stress gradient of 18 kPa/m.

In Situ Stresses



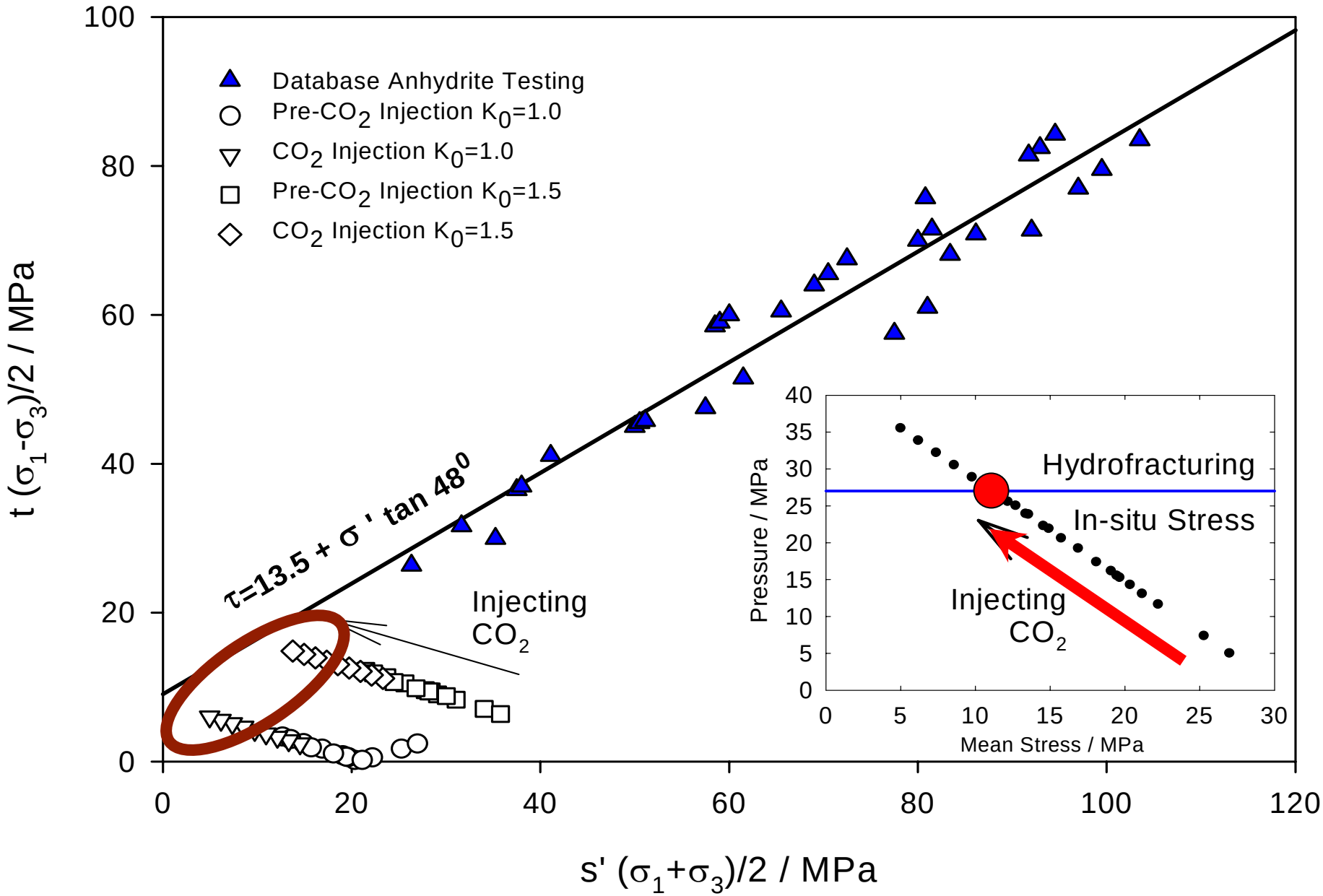
Pressure History of Weyburn Field



Analysis of Pressure History

- Assessing initial pre-CO_2 injection conditions for a CO_2-EOR storage project is challenging due to the previous history of exploitation and production within the reservoir.
- A geomechanical analysis of the system was carried out using the MEM and the pressure information.
- The large stiffness of the reservoir and low pressure gradients leads to a minimum distortion of the reservoir and bounding seals, and small changes in the in-situ stresses.
- **Consequently, the hydraulic integrity of the caprock has likely been preserved during pre-CO2 injection history of the reservoir.**

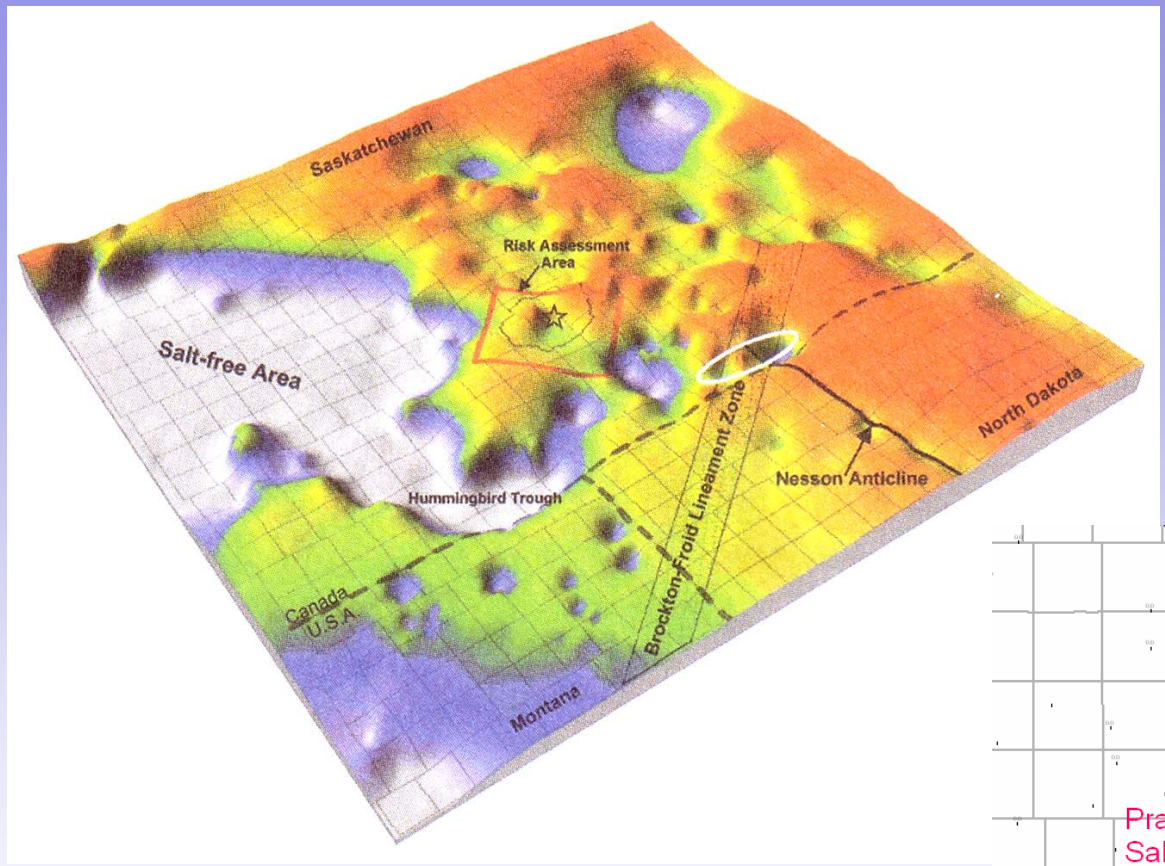
Geomechanical Performance of Caprock

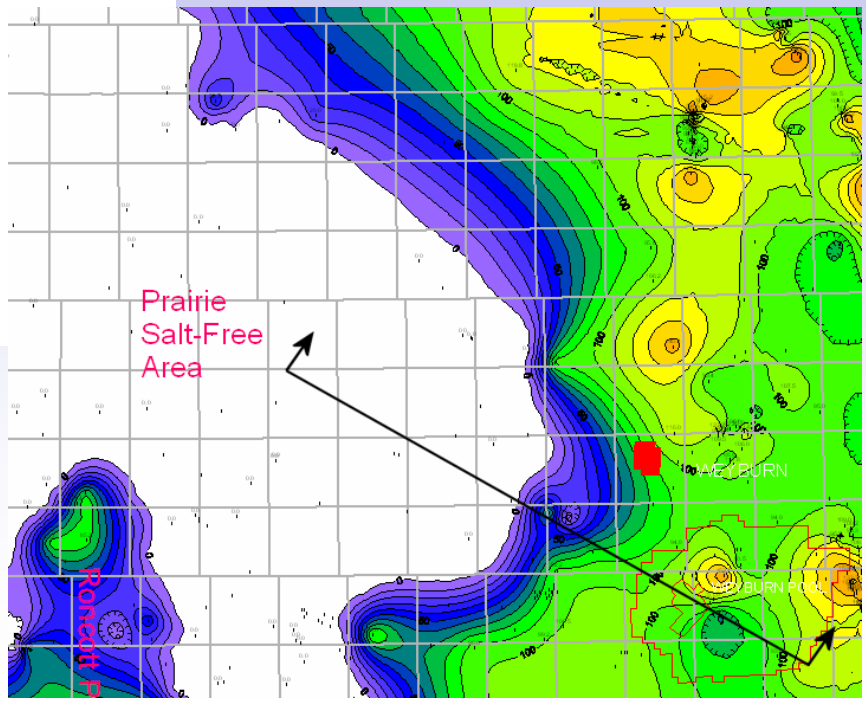


Impact of Elevated CO_2 Injection Pressures

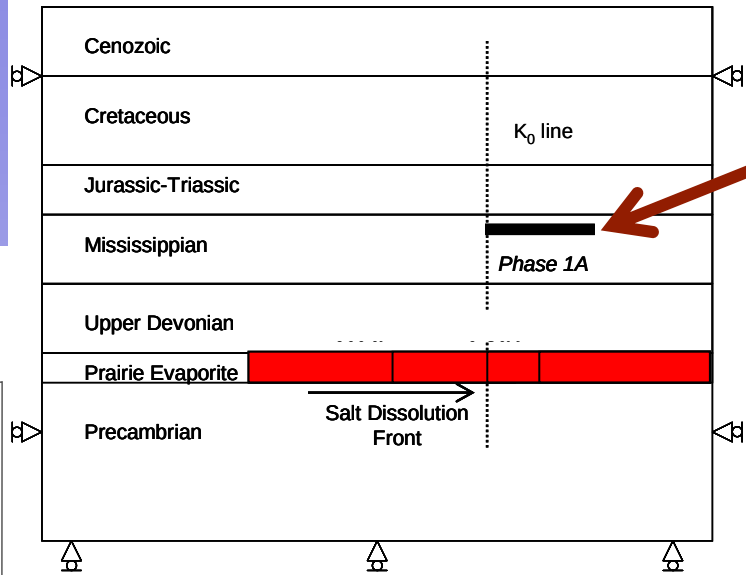
- To study the role of injection pressures on the post-EOR or CO_2 storage phase of the project, the pressures were increased ***synthetically***.
- Results indicated that hydraulic fracturing will most likely be the mechanism of failure within the bounding seals rather than shear failure

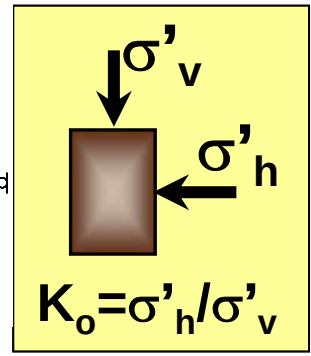
MEM and Salt Dissolution

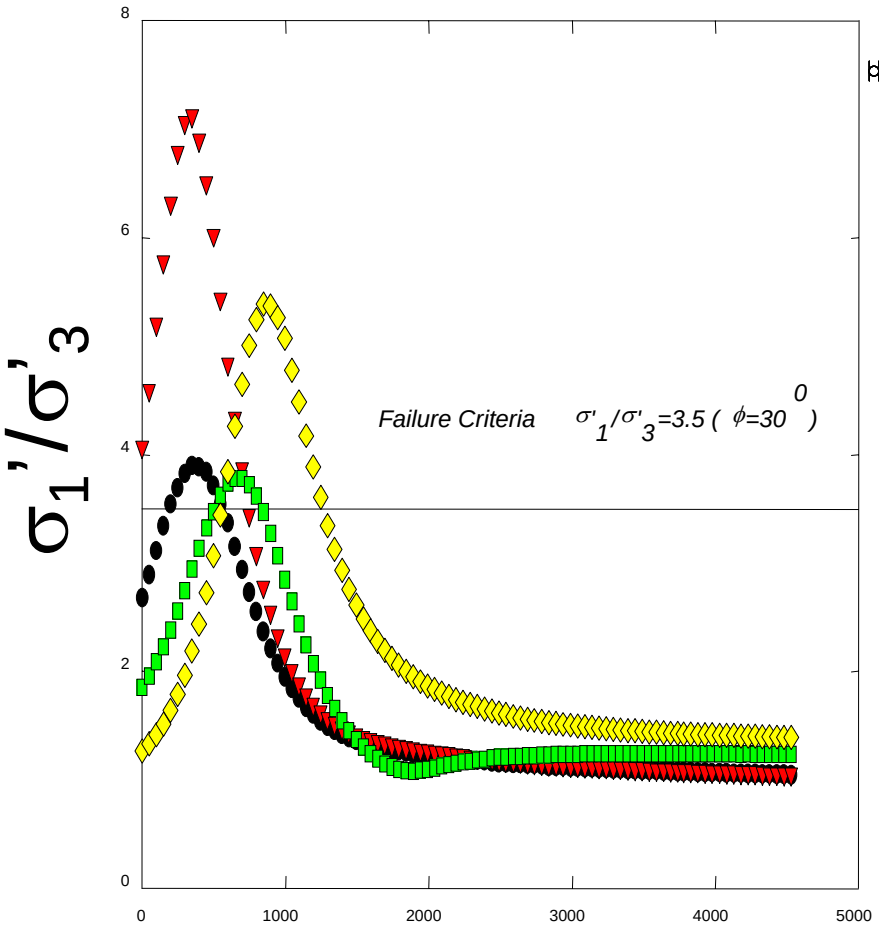




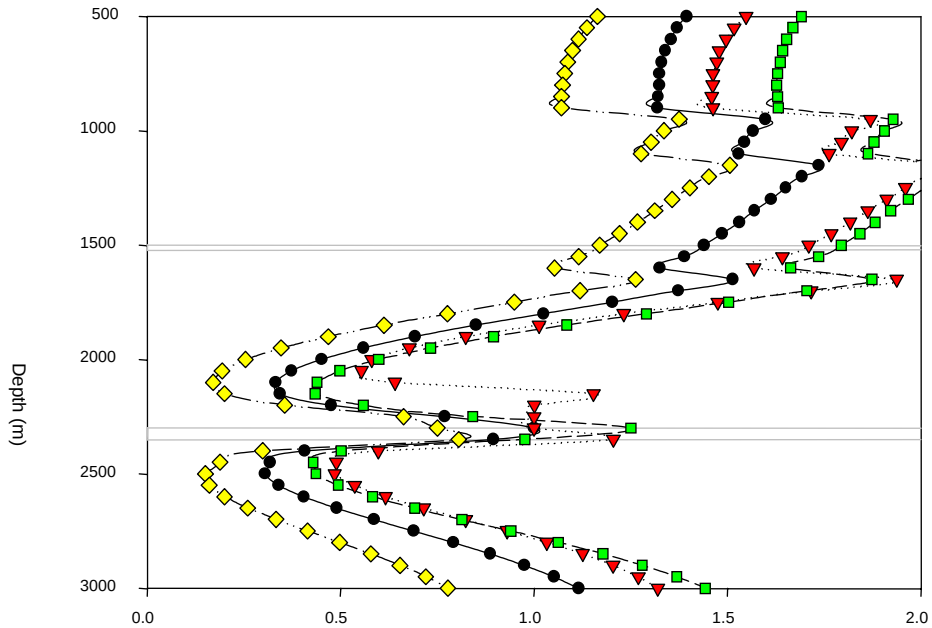
Stress Changes due to Salt Dissolution







Distance along reservoir, m



$K_o = \sigma_h'/\sigma_v'$

Summary

- A mechanical earth model was developed to evaluate the geomechanical performance of the Weyburn Field as part of the performance assessment studies undertaken for the IEA Weyburn CO_2 Monitoring and Storage Project.
- Simulation studies using the mechanical earth model support the conclusion that the integrity of the bounding seals has been preserved during years of production and injection prior to CO_2 injection.
- In addition, hydraulic fracturing (maximum injection pressures) will likely control the maximum volume of CO_2 that can ultimately be stored in the Weyburn Field

Phase II Research Activities related to the Mechanical Earth Model for Weyburn

- Measurement of in situ stresses
- Characterization of natural fractures from the Frobisher formation to the top of the bedrock
- Increased understanding of the flow properties of these fractures as well as fractures within the reservoir.
- Wellbore integrity issues such as cement permeability and its prediction, permeability of cement-casing and cement borehole interfaces
- Development and validation of techniques to evaluate wellbore system transport properties.
- Impact of thermal effects on caprock integrity
- Refinement of the hydro-geomechanical properties database for key geological layers within the System Model.